Remarks

Applicant acknowledges that the proposed drawing correction has been accepted.

Applicant also acknowledges the Examiner's continued requirement for a copy of the textbook entitled "Robot Manipulators: Mathematics, Programming and Control" by Richard P. Paul. Applicant has obtained and encloses herewith a used copy of the book. Some highlighting is seen in the text but such markings were not made by applicant or by anyone on his behalf.

Claim 1 has been amended to more clearly define the invention recited therein. As presently amended, claim 1 requires the formulation of a total potential function as a weighted sum over all program steps of the contributions from all attracting pairs at a step, all repelling pairs at a step and the limits of the points whose values are adjusted at the step. The total potential function is subjected to a mathematical optimization analysis to find the prospective locations of workpieces and base links and joint values to minimize the total potential function. Such optimization analysis produces an arrangement of each workpiece and device in the cell in which attracting pairs are coincident, repelling pairs are spaced and the joint values are within their limits of motion.

Applicant's formulation of the potential function is described at pages 11 through 13 of his specification and his process for mathematically optimizing the function is found on the following pages of his specification.

Claim 1 also recites that a tree structure of program steps be entered into the data base of the programmable computer used in execution of the recited process. The root nodes of the specified tree structure comprises initial values of each workpiece processing device in the manufacturing cell at an initial time and the child nodes contain alternative motions of the device in an alternative operation. And the child nodes contain device joint values to be attained at the completion of a joint motion in a particular alternative device operation. This data base tree structure is used in the optimization analysis of attracting pairs, repelling pairs, and joint values.

Claim 1 as currently amended defines a new, potential function optimization process for arranging one or more workpieces and one or more workpiece processing

devices in a manufacturing cell. The claimed process can produce a cell layout for more than one product such as related parts for different vehicles (see specification, page 5 and Figure 12). Mathematical steps in the process can be programmed into commercial software. But no commercial software discloses the claim 1 process and its requirement of formulating a potential function as a weighted sum over all processing steps, the potential function sum including the specified workpiece(s) and workpiece processing device(s) attracting pairs, repelling pairs and joint motions. And no combination of the disclosures of the references of record and of commercially available software teaches or suggests the claim 1 method. Dependent claims 2-9 add inventive process features to the process invention recited in claim 1.

The Rejections

Claims 1-4 and 8-9 are rejected under 35 U.S.C. 103(a) as being unpatentable over Matsuzaki et al., U.S. Patent 5,357, 439 and Applicant's admission, at lines 18-19 of page 13 of this specification, in view of Spector, U.S. Patent 6,004,016. Claims 5-7 are rejected under 35 U.S.C. 103(a) as being unpatentable over Matsuzaki et al. and Spector, and further in view of Tandler, U.S. Patent 5,949,693. The Examiner is respectfully requested to reconsider these rejections for the following reasons.

Applicant's Response

The focus of the following remarks and arguments for patentability are directed at claim 1, the only independent claim, because it is believed that claim 1 and its eight dependent claims are allowable over the prior art.

The Examiner states that the Matsuzaki et al patent discloses the claim 1 tree structure of program steps at column 22, lines 39-43; the claim 1 attracting pairs of coordinate systems at column 2, line 67 through column 3, line 2; the optimization of attracting pairs at column 8, lines 34-37; and subjecting the locations and joint values to a mathematical optimization analysis at column 3, lines 3-6.

The Matsuzaki et al reference to a "tree-structure manner" in column 22 refers to fitting rods in holes of parts of their toy airplane product example. Of course, tree structures are a common construct for representing hierarchical information; even a

genealogical "family tree" is such a structure. Thus, the disclosure of a tree structure in Matsuzaki is relevant only if it represents information similar to that required in claim 1. It does not. The tree referred to in Matsuzaki, column 22, lines 39-43 represents "the positional relation among the parts composing each product." This has nothing to do with motion sequences of workpiece processing devices which are the specified contents of the claim 1 tree structure.

The Matsuzaki et al disclosure at column 2, line 67 through column 3, line 2 states that "manufacturing equipment is allowed to be arranged by freely combining a positioning unit providing two or more horizontal conveying mechanisms and a posture positioning unit." The Matsuzaki et al disclosure at column 3, lines 3-6 speaks of finding an optimum equipment arrangement for a product specification. These general disclosures certainly do not suggest the claim 1 process of formulating a total potential function ...of the contributions of all attracting pairs.., repelling pairs..., and ...limits of joints and mathematically optimizing the function to locate workpieces and devices. In fact, Matsuzaki et al rely principally on a computer operator to work out a specification of manufacturing operations for a product by visually manipulating images on the computer screen. The Matsuzaki et al computer is programmed to produce images but not to mathematically optimize a manufacturing cell using a potential function.

The Matsuzaki et al disclosure at column 8, lines 34-37 refers to Figure 4. Block 3-2 is said to be a data input unit to which a human operator can input an instruction in an interactive manner when designing the manufacturing process. There is no disclosure of the claim 1 mathematical process.

The Matsuzaki et al procedure for automatically defining the layout (column 26, line 57, to column 27, line 13) is based only on checking the motion limits of a machine against the range of motion required in a part insertion operation. And the Matsuzaki disclosure is limited to the manufacture of a single product; there is no capability described for producing more than one product in a manufacturing cell. The layout procedure advances one assembly step at a time, checking for range of motion and interference. There is no prescription for what recourse to take if interference is detected. The automatic method only refers to Step 5 (column 26, line 11), which describes a manual method in which an operator makes manual selections. So the automated method

is not actually described in a way that would allow a person skilled in the art to reproduce the Matsuzaki et al practice. Moreover, Matsuzaki assumes in the description of the layout process that a robot performs a single insertion operation. One must presume that after the insertion operation the part is transferred to another machine for the next assembly step. There is no consideration that the robot might perform a sequence of operations and that the location of the robot in the work cell must be such that its motion is free of interference for the entire sequence. The claims 1-9 processes require and achieve all this, and for more than one part.

Thus, Matsuzaki et al disclosure does not teach or suggest the mathematical optimization of an objective function. It has no hint of potential functions, neither attracting nor repelling.

The Examiner states that the Spector '016 patent complements the Matsuzaki et al disclosure by disclosing a process considering repelling pairs of objects.

Spector describes a method of planning a collision-free motion of one or more robots or other devices moving in a common space. Spector's method begins with top-level motion requests that are translated into a coarse motion plan that is then adjusted using control signals derived from artificial repelling potentials between parts. Thus, Spector does not describe or suggest the use of the combination of attracting pair functions, repelling potential functions and joint value functions as required in the claim 1 process.

Moreover, Spector's control signals are used only for planning a collision-free motion, if one exists. The Spector disclosure does not address the manufacturing cell layout question. It only addresses the question of finding, <u>for a given layout of devices</u>, how to plan motions. In the Spector process, the coarse level planner does not use potential functions, but rather is based on a configuration space decomposition in which each cell is labeled "full", "free," or "mixed," according to its collision status. The potential functions are used only at the fine adjustment level to avoid collisions.

Thus, if one skilled in the art of manufacturing cell layout combined the disclosures of Spector and Matsuzaki et al, that person would (following Matsuzaki) consider one assembly operation at a time, pick a location of a robot based on gross matching of robot working volume to the required motion to mate two parts, then

(following Spector) that cell layout person would plan the detailed motion with fine adjustments based on repelling potentials. In doing so, the cell layout person would not have addressed the primary question of the subject patent application, which is to consider layout design to accommodate collision-free motion over multiple production steps for each product and over multiple distinct motion sequences required to produce multiple products. Thus, Matsuzaki and Spector taken together in no way disclose or suggest the claim 1 invention.

The disclosure of the Tandler '693 patent is combined with the teachings of the Matsuzaki et al patent and the Spector patent in rejection of claims 5-7. Claims 5-7 include assigning the attracting pairs of claim 1 as consisting of attraction between the origin points of coordinate systems of the pairs. Additional limitations on constraints of the coordinate systems are imposed in claims 6 and 7. Applicant's comments with respect to the absence of a relationship between the recitation of claim 1 and the disclosures of the Matsuzaki et al '439 patent and the Spector '016 patent have been stated. The issue is whether Tandler teaches the claims 5-7 processes in their use of coordinate systems in formulating attracting pairs.

Figure 16a of Tandler illustrates an initial coordinate system, interim coordinate systems and a final coordinate system for a data reference frame (DRF) for a machine part. However, this figure and related text merely shows a sequence of partial alignments necessary to bring two coordinate systems into full alignment. But this is not the inventive substance of claims 5-7 as combined with claim 1. The full text of claims 5-7 uses the coordinate systems as part of a mathematical optimization analysis of a potential function including attracting pairs, repelling pairs and joint values. And the optimization of the potential function brings the attracting pairs into alignment while separating the repelling pairs.

There is no discussion in the Tandler patent '693 of developing a measure of the degree of misalignment of attracting pairs as is provided explicitly by the attracting potential functions required in claim 1. It is the attracting potential function that drives devices towards their targets in the claim 1 method in a mathematical optimization. Tandler does not use or disclose such potential functions or such optimizations. His aims

are entirely different. He does not therefore teach the formulation of attracting pairs recited in claim 1 or claims 5-7.

The combined teachings of Matsuzaki et al, Spector, Tandler and prior art software capabilities referred to in applicant's specification do not teach or suggest the processes of claim 5-7.

Conclusion

Claim 1-9 recite specific processes for manufacturing cell layout involving one or more workpieces and processing devices. These claims each comprise steps requiring specified data entry and the formulation of a total potential function as a weighted sum over all program steps in cell layout of the contributions from all attracting pairs at a step, all repelling pairs at a step, and the limits of those joints whose values are to be adjusted at the step. The total potential function is subjected to a mathematical optimization analysis to find the prospective locations of workpieces and base links and the joint values of the devices to minimize the total potential function. These steps of the claims 1-9 processes achieve an arrangement of each workpiece and device in a manufacturing cell in which the attracting pairs of coordinate systems are coincident, the repelling pairs are separated, and the joint values all lie within said limits of motion. The combined disclosures of Matsuzaki et al, Spector, Tandler and applicant's statement at page 13 of his specification do not teach or suggest the processes recited in claims 1-9. Accordingly, it is requested that the rejections of the claims be removed, that the claims be allowed, and that this case be passed to issue.

Should the Examiner feel that a discussion by telephone could advance any matter in this case he is urged to call applicant's attorney at the telephone number listed below.

Respectfully Submitted,

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I hereby certify that this correspondence is, on the date shown below, being deposited with the United States Postal Service with sufficient postage as first class mail, in an envelope addressed to the Commissioner of Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on : 5/14/04.

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